TOPIC 17 — EQUILIBRIUM

17.2: THE EQUILIBRIUM LAW IN FURTHER PRACTICE

IB Chemistry

T17D05

17.2 Equilibrium Law - 2 hours

- 17.2.1 Solve homogeneous equilibrium problems using the expression for Kc. (3)
- Just as discussed in Topic 07, the equilibrium constant for a reaction can be derived using the chemical equation and coefficients within.
- For the dynamic equilibrium of the decomposition of phosphorous pentachloride, the value for K_c is:
  - $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

- The value of K_c indicates the position of equilibrium

17.2 – Homogeneous Equilibria Calcs

- All equilibrium examples in IB Chemistry will be of a homogeneous nature for simplicity
- You must be able to
  - Confidently write equilibrium expressions
  - Put numbers to the process (use data to solve for K_c, etc)

17.1 – Example #1

- Nitrogen (II) oxide, NO, is a pollutant released into the atmosphere from car exhausts. It is also formed when nitrosyl chloride, NOCl, dissociates according to the following equation:
  - $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$
- Different amounts of each of the reactants were studied at two different temperatures, 503K and 738K.

	Concentration (mol cm^{-3})		
Temperature (K)	**NOCl**	**NO**	**Cl_2**
503	2.33×10^{-3}	1.46×10^{-3}	1.15x10-2
738	3.68×10^{-4}	7.63×10^{-3}	2.14×10^{-4}

- A: write the expression for K_c
- B: Calculate K_c for both temps given
- C: Is the forward reaction endo- or exo-thermic? Base it on Topic 7 ideas

Example #1 - answers

- _____
- At 503K
  - _____
- At 738K
  - _____
- Endothermic: The value of K_c is greater at 738K; K_c increases with temperature, with the forward reaction being favored to increase the proportion of products in the equilibrium mixture.

7.2 – Example #2

- The acid-catalyzed hydrolysis of ethyl ethanoate can be achieved by mixing the ester with dilute hydrochloric acid H^+

$$CH_3CO_2H(l) + C_2H_5OH(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l)$$

- If 1.00 mol of both ethyl ethanoate and water are mixed, in dynamic equilibrium 0.30 moles of ethanoic acid is found in the mixture
- Calculate K_c at this temperature

17.2 – Example #2 - answers

- First set up the equation as follows:

$$CH_3CO_2H(l) + C_2H_5OH(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l)$$

Starting amount (mol)	1.00	1.00	0.00	0.00
Equilibrium amount (mol)				0.30

- In taking into account the coefficients of the equation:

Starting amount (mol)	1.00	1.00	0.00	0.00
Equilibrium amount (mol)	(1.00-0.30)	(1.00-0.30)	0.30	0.30

- In order to put these amount in the equilibrium expression to find K_c, they must be values of molarity (mol cm^{-3}) and not just moles (mol)

Equil. Conc. (mol dm^{-3})	0.70/V	0.70/V	0.30/V	0.30/V

- $\dfrac{[\quad]}{[\quad]} \qquad \dfrac{[\quad]}{[\quad]} \qquad \dfrac{\quad}{\quad}$

17.2 – Example #3

- An organic compound X exists in equilibrium with its isomer, Y, in the liquid state at a particular temperature
  - $X(l) \rightleftharpoons Y(l)$
- Calculate how many moles of Y are formed at equilibrium if 1 mole of X is allowed to reach equilibrium at this temperature, if K_c has a value of 0.02

17.2 – Example #3 - answers

- Let the number of moles of Y at equilibrium = y moles

	X(l)	⇌	Y(l)
Starting amount (mol)	1.00		0.00
Equilibrium amount (mol)	(1.00-y)		y
Equil. Conc. (mol dm^{-3})	(1.00-y)/V		y/V

- The K_c value, which is given as 0.02, can be set equal to the expression:

$$\frac{\quad}{\quad} \qquad \frac{\qquad\qquad}{\qquad\qquad} \qquad \frac{\qquad\qquad}{\qquad\qquad}$$

- In the expression, the concentration (or # mol) can be calculated for y.

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17.4 – Example #4

- Phosphorous (V) chloride undergoes thermal decomposition as follows
  - $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
- The equilibrium expression is as follows:
  - $K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$
- Some PCl_5 was placed in an evacuated flask of volume 1.0 dm^{-3} at 500K.
- An equilibrium was then established in which the concentration of PCl_5 was 4.0×10^{-2} mol dm^{-3}.
- The value of K_c for the reaction at 500K is 1.00×10^{-2}.
- Calculate the concentration of chlorine in the equilibrium mixture

17.4 – Example #4 - answers

- Let the concentration of Cl_2 at equilibrium = x mol dm^{-3}

	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$		
Equil. Conc. (mol dm^{-3})	4.0×10^{-2}	x	x

To solve for the moles of x, set up the equilibrium expression:

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

Solve for x, and find: